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Advances in Solar Radiometry and Metrology

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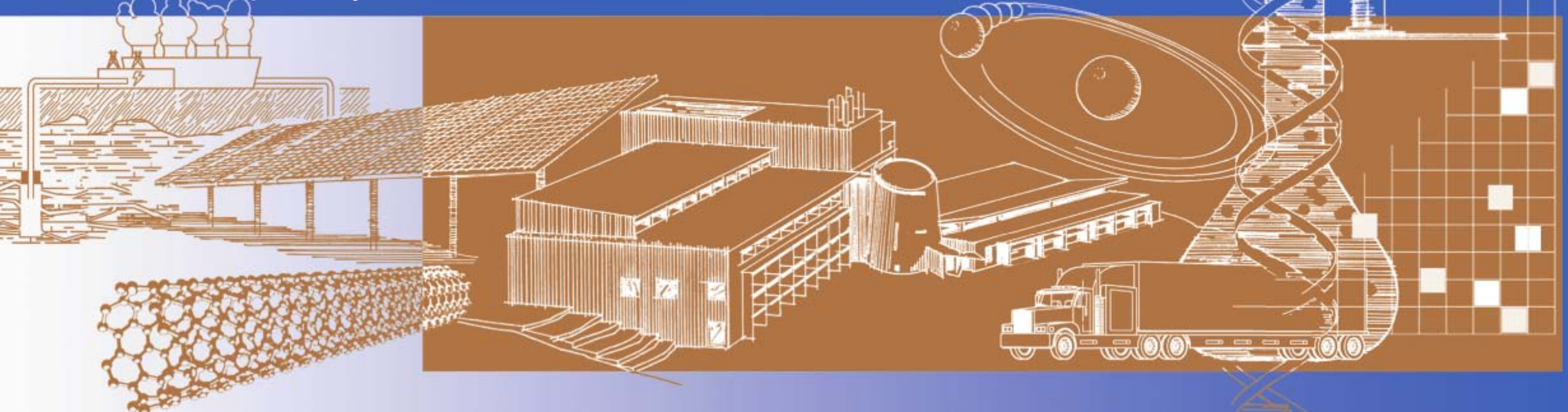

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ABSTRACT

The Solar Radiometry and Metrology task at the National Renewable Energy Laboratory (NREL) provides traceable optical radiometric calibrations and measurements to photovoltaic (PV) researchers and the PV industry. Traceability of NREL solar radiometer calibrations to the World Radiometric Reference (WRR) was accomplished during the NREL Pyrheliometer Comparison in October 2003. The task has calibrated 10 spectral and more than 180 broadband radiometers for solar measurements. Other accomplishments include characterization of pyranometer thermal offset errors with laboratory and spectral modeling tools; developing a simple scheme to correct pyranometer data for known responsivity variations; and measuring detailed spectral distributions of the NREL High Intensity Pulsed Solar Simulator (HIPSS) as a function of lamp voltage and time. The optical metrology functions support the NREL Measurement and Characterization Task effort for ISO 17025 accreditation of NREL Solar Reference Cell Calibrations. Optical metrology functions have been integrated into the NREL quality system and audited for ISO17025 compliance.

1. Objectives

This project addresses technical challenges regarding analysis tools, access to data, uncertainty of analysis, standardization of assumptions, and characterization of solar resource on technologies. We provide technical expertise and input to standards and codes development to address technical issues regarding solar radiation data and measurements affecting the Fundamental Research, Advance Materials and Devices, and Technology Development components of the Solar Program Multi-Year Technical Plan [1] for Flat Plate Photovoltaics, Concentrating Solar Power Systems, Solar Heating and Lighting, and New Concepts. Our objective is to provide the lowest uncertainty and most accurate, as appropriate, optical radiation measurements and data that meet the needs of the solar researcher and industry partners.

2. Technical Approach

Our approach to meeting solar research and industry needs in optical calibrations and measurements is to provide data of known uncertainty that is traceable to national standardizing laboratories and internationally recognized reference standards, such as the the National Institute of Standards and Technology (NIST) Standard of Spectral Irradiance and the World Radiometric Reference (WRR) [2]. We participate with consensus standards organizations such as the American Society for Testing and Materials (ASTM), International Standards Organization (ISO), and International Lighting Commission (CIE) to develop standards assuring high quality solar energy industry products. The task assures traceable optical radiation measurements of know uncertainty for the NREL solar program research community and solar industry partners by participating in the NREL quality system according to the requirements of ISO 17025. Reference standard and working instruments and systems are characterized and calibrated with documented procedures against national and international standards with as short a 'traceability chain' as possible to accurately quantify and reduce uncertainties. Calibrations, measurements, and technical expertise are provided on a programmed and as-requested basis.

3. Results and Accomplishments

We describe advances in the technical areas of (1) maintaining and quantifying the stability of NREL solar radiometric reference with respect to the WRR, (2) characterizing pulse solar simulator spectral distributions, (3) quantifying the magnitude of thermal offsets in pyranometers for measuring global solar radiation, and (4) identifying alternative methods for correcting hemispherical solar radiation data for variations in responsivity over a year. In addition, the September 2004 ISO 17025 accreditation of the NREL Photovoltaic Testing Group PV Reference Cell Calibration activity required the integration of the appropriate optical metrology functions into the PV Testing Group Quality System. Successful external and internal audits resulted in the ISO 17025 accreditation for the activity.

3.1 WRR Traceability

The project supported the NREL Pyrheliometer Comparison (NPC) Sept. 23 - Oct. 3 2003 [3]. The object of the comparison is to confirm the stability of NREL reference radiometers for broadband calibrations, and transfer WRR to participating radiometers, according to WMO protocols [4]. Individual instruments are compared to a *transfer standard group* (TSG) of absolute cavity radiometers that participated directly in International Pyrheliometer Comparisons (IPC) sponsored by the World Meteorological Organization (WMO). Twenty-seven cavity radiometers participated, including instruments for the Florida Solar Energy Center (FSEC), US DOE Atmospheric Radiation Monitoring program, NASA Langley Research Center, and National Oceanic and Atmospheric Administration. Pooled standard deviation of the TSG radiometers (with four from NREL) was 0.06%, confirming excellent stability of the NREL solar radiometric references, as shown in Fig 1.

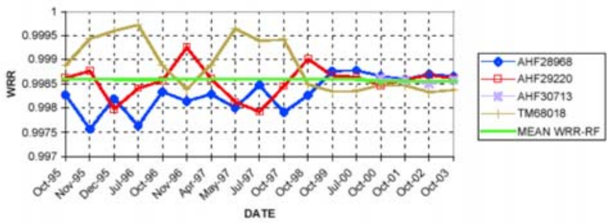

Fig. 1. History of WRR correction factors for NREL reference absolute cavity radiometers through NPC 2003.

3.2 Pulse Solar Simulator Characterization

The upgraded Pulse Analysis Spectroradiometer System (PASS2) classified six industry, NREL, and FSEC flash simulators according to ASTM solar simulator classification standard E-927. Figure 2 shows High Intensity Pulse Solar Simulator (HIPSS) pulse shapes as a function of wavelength. These unique results helped identify sources and magnitudes of artifacts in PV cell test results [5].

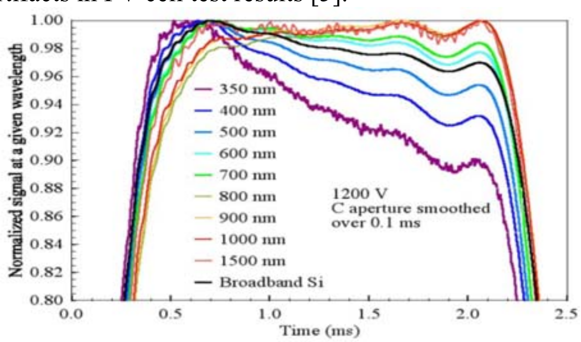

Fig. 2. PASS measured HIPSS pulse shape vs. wavelength.

3.3 Pyranometer characterization

We used the NREL infrared blackbody calibration system to evaluate the equivalent shortwave thermal error signal in the detectors [6] as a function of net infrared. Responsivity computed form the blackbody calibrations is used to correct pyranometer calibrations by up to 1.5%. We also developed a model for pyranometer responsivity as a function of day number, zenith angle, and net infrared irradiance closely duplicating annual variation in pyranometer responsivity [7] (see Fig. 3.)

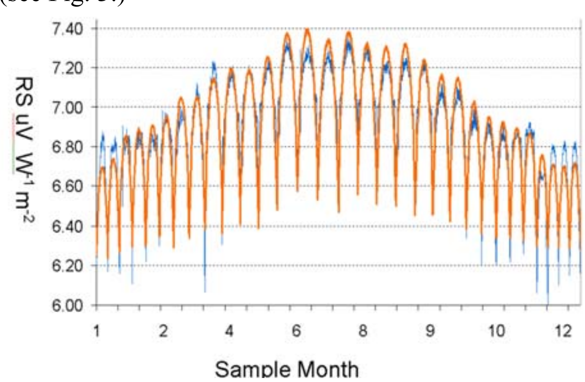

Fig.3. Measured (dark line) responsivity (Rs) of pyranometer and modeled (smooth line) responsivity as function of day number, zenith angle, and net infrared

4. Conclusions

These advances assist PV researchers and industry to identify measurement artifacts, assure accurate classification of PV products, reduce uncertainty in, and improving solar radiometric data. ISO 17025 accreditation for PV reference cell calibration reinforces NREL quality data in support of the solar industry.

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